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MULTIMOBIL 2.5

SP

Function Description

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Circuit Description

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6 Circuit Description

6.1 Master Card D915

6.1.1 Power Supply

The +15, 0V, -15V and +5V, 0V voltages are obtained from the SMPS through the connector X15.
The reference voltage for the Microcontroller (J31) is 5V and it is generated by R119, C85, and J30.

6.1.2 RESET Generation

The $\overline{RST}$ signal is generated by IC J40 (MAX700 : power supply monitor with reset) at power ON. The switch SW2 also allows for manual reset of the system.
On actuating SW2 ON, reset is generated by J40 which is applied to $\overline{RST}$ of J31.

6.1.3 Crystal Operation

The 12 MHz Quartz crystal forms a Pierce Oscillator along with the two capacitors C93 and C95. The output of the oscillator is a 12MHz sinusoidal wave which is applied to XTAL1 and XTAL2 inputs of J31 for providing timings for internal operations of the microcontroller.

6.1.4 Microcontroller

The microcontroller J31 outputs multiplexed lower order address bus and the data bus on port 'P0' and higher order address bus on port 'P2'.
The control signal $\overline{RD}$, $\overline{WR}$ along with A8-A15 are provided to J28 (GAL) to generate the chip select signals for accessing various peripherals.
The status signal $\overline{PSEN}$ is used for reading external program stored in EPROM J32.
The $\overline{EA}$ 'LOW' allows accessing the external program memory.
Different signals for controlling various operations of the entire system are provided by the Microcontroller on its ports P1, P3, P4, P5.
The analog inputs AN0 - AN6 are used for monitoring analog signals.
The pins TxD and RxD are used for serial communication between the processor and the external device such as a Computer for servicing.
The Service switch ST provided at pin P4.5 is used for operating the Unit in the service mode.

6.1.5 Octal Latch

The multiplexed address and the data bus is separated by the octal latch J27.
At the active ALE signal, the lower order address (A0-A7) is latched.

6.1.6 GAL

Since Memory mapping technique is used, the chip select signals for various peripheral devices are generated by the Gated Array Logic IC J28. The inputs are the

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address lines (A8 - A15), and the control signals $\overline{RD}$ and $\overline{WR}$. The output lines are $\overline{CS1}$ to $\overline{CS8}$.
These output chip select lines are generated on the basis of the logic implemented in the program stored in the GAL.

6.1.7 EPROM

The entire program is stored in a single EPROM J32.

6.1.8 NVRAM

The 2 Kbyte NVRAM stores the variables during the opertion of the unit.
A0 - A10 and D0 - D7 are the address and the data lines provided to the RAM. The first 2K bytes of entire memory space 0000H to 07FFH is used as RAM.

6.1.9 Serial Communication

TxD, RxD are provided to the serial communication port of D915. Various activities of the unit can be controlled by an external device such as a PC. The serial port is meant for testing and service purposes.

6.1.10 Keyboard

The keys are accepted through X12 from D936.
The keys kV+ , kV -, mAS+, mAS- are accepted on the data bus through J38 and J37 at the address 9000H.
The ON, OFF signals are routed via X12, D915, X10 to D920.

6.1.11 Display

The data bus, the control signal $\overline{WR}$ and the chip select signal $\overline{CS2}$ are provided to the Display Driver J24 on D932 through X1. Writing the control word and the string of 8 byte data at the addresses 8000H and 8800H respectively displays the kV and mAS values and lights up function related LEDs on D915.

6.1.12 kVsoll and mAsoll

The kVsoll and mAsoll values are generated by Dual Digital to Analog Converter J17 and the Opamp J13 acting as I - V converter.
The microcontroller J31 outputs the digital values of kVsoll and mAsoll on the data bus at address A000H ($\overline{CS3}$) and A100H ($\overline{CS4}$) respectively. The reference current for DAC is adjusted by means of presets P6 and P7.
The kVsoll and mAsoll are fed back to the AN3 and AN4 pins of J31 for ensuring their proper values. These soll values are also used for regulation of kV and mA.
The kV soll ratio is 1 V = 30 kV and the mAsoll ratio is 1 V = 20 mA.

6.1.13 Line voltage monitoring

The actual mains Line voltage stepped down & converted to DC and through differential amplifier it is fed to V-Bat input point of ADC . This DC voltage is monitored every 5 second in standby mode of unit and line voltage is displayed

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during first step of hand release switch for radiography. If the measured Line voltage is less than 200 volts , microcontroller sends one signal to switch ON the LN contactor which will support extra voltage through auto transformer for 2.5 KW power generation. This switching ON/OFF of LN contactor is done every 5 sec in standby mode of unit. In preperation and exposure mode contactor retains its position. After 5 second of each termination of radiography Line voltage is monitored once again.

6.1.14 kV Feedback

The actual kVp across the tube is stepped down and fed back to the Master card D915 at pins 1, of X8 as PKV with respect to the common terminal at pin 3.
PKV is passed through the voltage follower J5 and then fed to the Differenial Amplifier formed by J5 to produce kVist used for kV regulation.
(kVist ratio is 1V= 20 kV)
As no differntial configuration is used, NKV part is ignored by grounding it.
kVist is fed back to AN7of J31 for monitoring purpose.

6.1.15 IH Feedback

The filament current feedback is taken from the Interface card D920 through X11.1.
J7 provides a gain of 5 to Ih.
The AC filament current Iheiz is converted in DC value Ih by RMS-DC converter J6.
J9 provides an approprate gain to Ih (that can be adjusted by preset P5) so that the ratio 1V = 1A holds true. Ih is fed back to J31 at AN2 for monitoring purpose and the same is used for Ih regulation.

6.1.16 mA Feedback

The tube current (JR) is fed back at pin 5 of X8 on D915 & is applied to the Differential Amplifer formed by J4.
The output JR represents the actual tube current mAist which is fed back to J31 at AN1 through J9 for monitoring purpose. JR is also used for tube current regulation.

6.1.17 kV Regulation

The kVsoll and kVist values are fed to the P-I controller formed by IC J10.
The difference between the kVist and kVsoll value is amplified to produce an appropriate error output, so as to compensate the error. The zener V12 limits the maximum output voltage of the error amplifier to 10V.
The error amplifier output is fed to PLL IC J3 which is used as voltage to frequency converter. The J10 output voltage produces an equivalent frequency REG at J3 output. For 10V, REG (the maximum firing frequency of the Main Inverter) is approx. 9.2 kHz. J3 is enabled by an active low INH2 signal provided by the microcontroller J31 at P4.1 through J23. During HT, J3 is enabled through INH2 and J3 results in a firing frequency of Main Inverter Igbt's, to result in actual kV in line with the required value.

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6.1.18 Filament Regulation

Filament Regulation is divided into two parts:

1. Regultion without high voltage : The filament current Ih is regulated. CPU J31 feeds the required filament current value to the input of DAC.
2. The actual tube current JR is regulated. J31 outputs the required tube current on the input of DAC. Depending upon whether the regulation is pre H.T or post H.T either Ih or JR is selected through HEIZ signal from J31 (P4.4) and used for regulation together with the corresponding value from the DAC. The output of the error amplifier J10 is fed to PLL J2 which is configured as voltage to frequency converter. The PLL J2 is enabled through INH1 signal from J31(P5.0) and generates a frequency in line with the output of error amplifier J10 to result in required filament current or the tube current.

6.1.19 mAs Integration

The actual tube current is applied to the input of V-F converter J1. The transfer ratio (Frequency to Voltage) of J1 is adjusted by preset P1. The output frequency is selected by J8 only when the kVist reaches 64% of its final value.
The output of J8 is fed to J31 as timer 0 clock .The timer 0 inside J31 is configured as timer counter which is preloaded with a count equivalent to mAs value.The incoming clock decrements the counter and on reaching ‘0’, generates an interrupt to terminate the exposure.

6.1.20 Control of the Firing Pulse Frequencies REG and CAL

REG is controlled by the signals INH2 and INH3 and it is enabled only when INH2=0 and INH3 =1 .
CAL is enabled only when INH1=0.

6.1.21 Generation of actual Firing Signals

6.1.21.1 Main Inverter Firing Frequency

The pulse duration of the actual firing signals of the Main Inverter is decided by the Monoshot Multivibrator J21 (IC 4538 Dual Monoshot Multivibrator) and R104, C66 and R105, C67.
The $\overline{RST}$ pin of J21 is normally high for its proper operation.
The outputs of J21 at pins 6 and 10 are out of phase. These signals are optically isolated by J39 and J41 and fed to the Main Inverter Driver (D61) through X20.14 and X20.18 .

6.1.21.2 Filament Regulator Firing Frequency

J18 is used to determine the pulse width of the the actual firing signals of the Filament Regulator. The IC J20 ensures that the firing pulses to the Filament regulator are out of phase. These signals are inverted by J22 and fed to the Filament regulator firing circuit on D915 through X11.13 and X11.16.

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6.1.21.3 Main Inverter Short Circuit Feedback SCM

During normal operation, the transistor V39 is ON and simultaneously the optocoupler is also ON. An active LOW error signal at X20.16 turns V39 and consequently J34 OFF. The J34 output becomes LOW to give the HIGH SCM (Main Inverter short circuit) signal. SCM is inverted by J22 and then it is fed back to the microcontroller J31 for taking the corrective action.

The three signals SCM , KVM and JIM are used for disabling the Driving pulses of the Main Inverter. This is done by ORing of these three signals by J14. At the occurrence of either of these three signals, $\overline{RST}$ goes LOW and its output is disabled.

6.1.22 kVmax, mAmax Feedback

6.1.22.1 KVM maximum kV

If the KVP value exceeds the reference value for 110kV at J12 (Comparator) its output generates the KVM signal. KVM is also fed back to J31 at P32 as T0 Interrupt for initiating necessary corrective action like stopping the exposure instantaneously.

6.1.22.2 JIM maximum mA

An increase in Ih or JR than the reference values of 4.4A and 71 mA respectively generates JIM. JIM is fed as T1 interrupt to J31.

6.1.22.3 IH Maximum

This error is similar to JIM. This is monitored during standby and preparation state and gives an interrupt if the filament current exceeds the maximum permissible current that is 4.2 Amperes.

6.2 Igbt Inverter Assembly D61

Igbt Inverter Assembly houses Igbt's configured as bridge inverter, along with Inverter Pcb D61 consisting of associated firing circuit, supply monitoring and short circuit sensing circuit.

6.2.1 Firing

With second step of exposure release switch pressed, the microcontroller prepares for the exposure loading the kV and mA values required for the exposure into the DAC. This control circuit residing on the Master Card D915 then generates the firing pulses for the inverter which are available at the connector X6 of the inverter PCB through interface PCB D920.

On Inverter PCB D61, J1 along with resistors R13, R14 and capacitors C5, C6 form the pulse stretching circuit which stretch the Disp1 and Disp2 pulses to 64 µ Sec (the resonating time of the LC load) maintaining 180° phase shift. These phase shifted pulses drive the Igbt drivers which in turn generate the gate firing pulses for the Igbt's.

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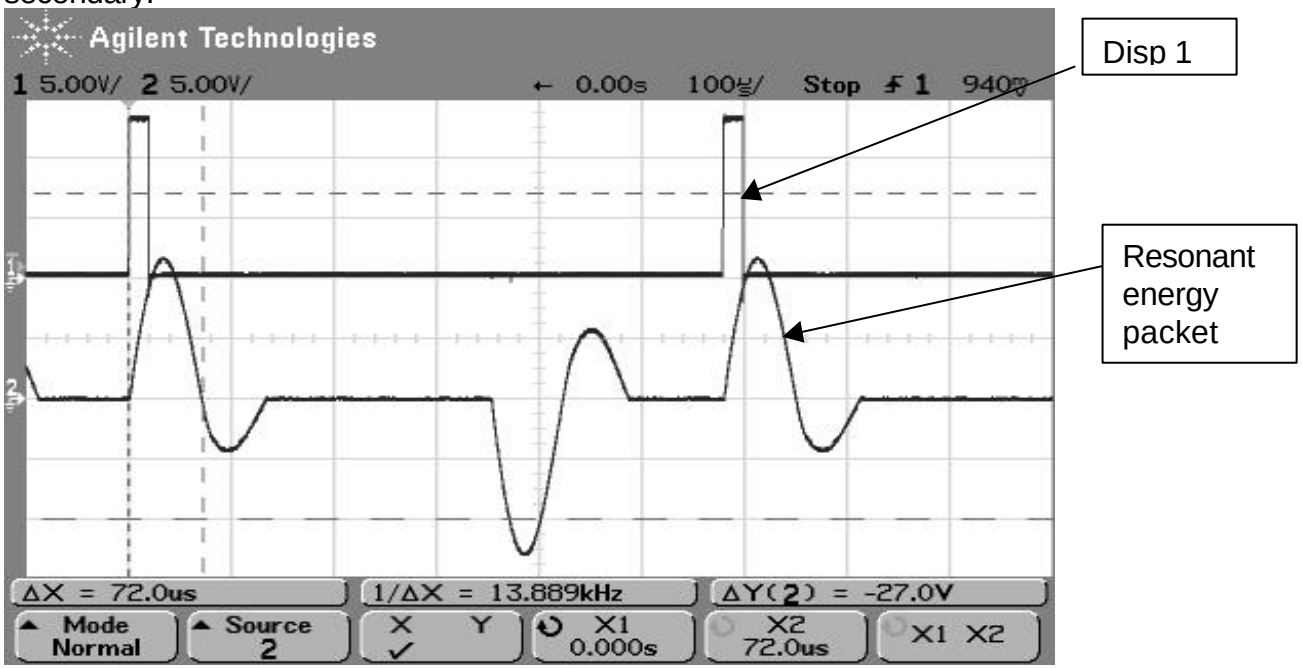
Resistors R1, R4, R7, R10 control the turn-on speed of the Igbt's. Resistors R2, R5, R8, R11 control the turn-off speed of the Igbt's.

6.2.2 Inverter

U/V is the primary widing of the HT trafo which is in series with external resonating capacitor C4 and external inductor L2.

With Disp1 pulse the current path is completed through DC(+), 3-1 of IG1, A3, U/V, C4, L2, A2, 1-2 of IG2, DC(-). After 64 µ Sec the gate pulse is turned off and the Igbt's are turned off. The resonating capacitor C4 which is now charged to a voltage greater than the bank voltage discharges via the free-wheeling diodes in anti-parallel to the Igbt's. The Waveforms for the energy packet flowing through the primary winding can be measured by connecting a current transformer across A3 or A2 .The waveform for the the same when Disp 1 is present is shown below.The turns ratio of the current tranformer used is 1000:1 with a 100 resistor across the secondary.



With Disp2 pulse the current path is completed through DC(+), 3-1 of IG2, A2, L2, C4, U/V, A3, 1-2 of IG1, DC(-). After 64 µ Sec the gate pulse is turned off and the Igbt's are turned off. The resonating capacitor C4 which is again charged to a voltage greater than the bank voltage discharges via the free-wheeling diodes.

The waveform for the energy packet flowing through the primary winding when Disp 2 is present is shown below.The turns ratio of the current tranformer used is 1000:1 with a 100 resistor across the secondary.

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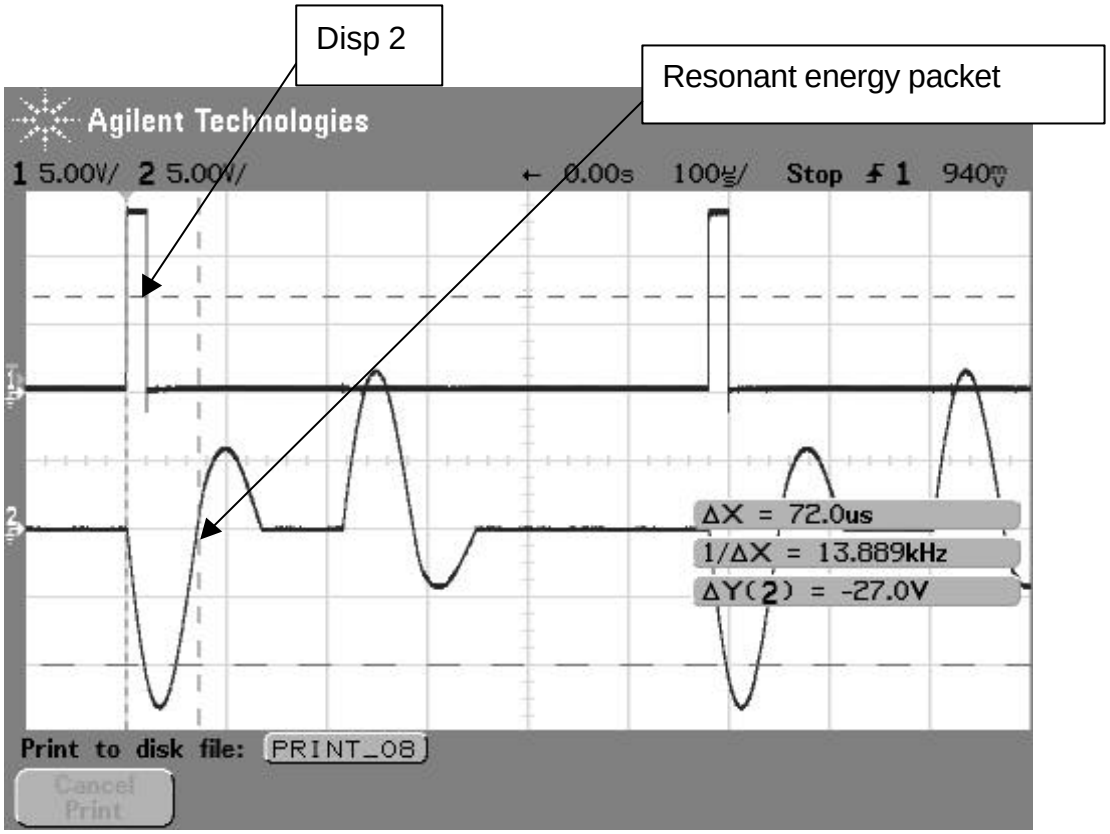


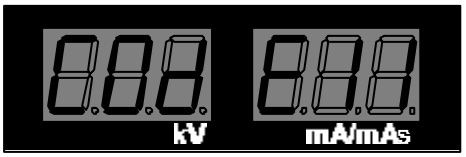
The resonant period for either pair of IGBT's firing should be between 64-72µ Sec and the peak to current should be approximately 125 Amps .

The firing pulses have a maximum frequency of 9.2 kHz ± 0.3kHz.

The presence of DC voltage is indicated by LED V1 on D61.

6.2.3 SCM

VCE of the Igbt is monitored continuously by the Igbt drivers. In case of short in any Igbt's VCE will increase resulting in generating of active low signal on ERR pin of the driver. ERR pin is normally held high by a pull-up resistor in D920. The ERR pin can go low if the supply voltage falls below 13V instead of 15V. When this signal is sensed by the microcontroller, firing pulses are inhibited and Error Code 11 is displayed, and the IGBT's are turned off.



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6.3 Interface PCB D920

6.3.1 ON/OFF Circuit

The mains voltage of 240 V ac appears across X1.1 and X1.2. The 15 Volts transformer T1 and regulator 7812 on the PCB provides the coil voltages for the On / Off relays K2 & K1. When Unit On switch is pressed, the circuit for Relay Coil K2 gets completed and causes the Relay K2 to energise. This causes the contact (5,7) of K2 to close which will provide the AC voltage to circuit points like SMPS (40 watts &120 watts) input and Contactor Coil connections it also causes contactor CS to pick up and provide the direct Line voltage to the Main Transformer T1 and to the full wave rectifier for charging the capacitor bank via the 47Ù parallel resistance. As the coil K2 energises the contact K2 (6,5) is establised and hence the unit remains On even if the switch is released.

When the switch is pressed, the Relay K1 coil is energised and this causes the Normally Closed contact K1 (4,6) of relay K1 to open thereby opening the circuit connections for relay K2. The Unit thus is turned Off.

6.3.2 Line voltage measurement

Incomming Line voltage is stepped down to 15 volts when input is 230 AC. It is converted to DC & filtered using capacitor. This DC voltage is further stepped down using resistor divider network and given to differential amplifier for line voltage measurement through ADC on Master card D915.

6.3.3 Power Supply Distribution

The following connections are routed through the Interface PCB D920.

1. X1.9 & mains neutral 240 V ac for Contactor US Coil Connections
2. X1.4 & X1.6 240 V ac for SMPS (40 watts) input supply
3. X1.5 & mains neutral 240 V ac for CS Contactor coil connections
4. LN on D920 & mains neutral 240 V ac for Contactor LN Coil Connections
5. X1.8 & mains neutral 240 V ac for SMPS (120 watts) input supply

The contactor US and LN coils are energised only when corresponding signal from the Master Card D915 is obtained. This is achieved through optocouplers J1 and J9 respectively. The contactor On signal from the Master Card D915 inturn drives optocoupler J1 / J9 which in turn K3 / K6 relay to connect the 240 V ac to the coil.

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6.3.4 Filament Circuit

The interface for the filament is built in a series regulator form. The filament is driven for the required heating i.e. of the predetermined value of current through an arragement of controller, driver circuit and final regulator circuit. Out of these three the controller circuit exists on the Master Card D915. The driver part J7 and the series regulator are formed on the Interface PCB D920.

6.3.5 Filament Supply and Heating

The DC supply of around 24 volts is obtained by SMPS 120 watts.This is then passed through bridge rectifier to avoid wrong connections of positive and negative terminals of SMPS & filtered to obtain a smooth DC by a bank of four 2200µF capacitors. The Bank of capacitors help in reducing the heavy current spikes that might result if a single capacitor of a large value is used. The collector voltage to V20 transistor is given through NTC 2.5R to reduce inrush filament current. The firing Pulses for the driver optocoupler J7 are the Drive1 and Drive2 pulses added together. These pulses switch the driving transistor for the regulator 2N2222. In this manner the Power transistor 2N3055 V20 is operated in the switching mode to obtain the pulsating DC for the filament heating.

6.3.6 Stand-by State

In the standby state of the system the filament is heated to 2 Amp. This value is decided on the basis that heating is below radiation value and sufficient enough to allow the radiation within 1.2 seconds of preheating.

6.3.7 Preparation State

This is entered when the exposure release switch is pressed half-way to make only first step contact. In this state the filament is boosted to get heated to a value so that the required mA (Tube Current) is achieved under exposure condition.

The maximum value of boosting current is restricted to 4.2 Amperes.

6.3.8 Filament Current Feed Back

The control circuit on the Master Card D915 receives the feedback voltage corresponding to the actual filament current inorder to achieve the filament current regulation during standby and boosting states and Tube Current / mA regulation in case of exposure state. For this purpose one 0.1 Ω resistor is introduced in series with the filament. This gives current to voltage converstion with the conversion factor of 100 mv = 1 A. This in turn is differentially amplified by the IC J8 to give the final current ratio of 1 V = 2 A.

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6.3.9 Tube Current Feedback

Similar to Filament current feedback the tube current feedback is taken from the Single Tank is available at X2.4, X2.5. The combinition of 100 Ù reistances in parallel give the tube current ratio of 1 V = 20 mA.

6.3.10 Collimator Supply

The collimator supply of 12 V ac is obtained from the mains Transformer and is made available on X12 connections after introducing a LED indicator and a 10 A protecting fuse.

6.4 Keyboard PCB D936

6.4.1 Keypad

No.	Identification	Description	Hex Code
1		Unit OFF	n.a.
2		Unit On	n.a.
3	kV +	kV increment	F7
4	kV -	kV decrement	EF
5	mAs +	mAs increment	FD
6	mAs -	mAs decrement	FB
7	DL_Serv	Service mode select	FE

6.4.2 Interface with Master Card

The keyboard switches are connected to the Master Card D915 through X12 connector. The switch action is conveyed to the Master Card by a switching 15 Volts signal. In normal condition when no key is pressed all the key lines are maintained at LOW. This in turn is reflected at the port 9000H as all high as FFH.

Whenever a key is depressed, it is connected to the 15 V dc line and the corresponding line on the port 9000H goes low. Thus the cooresponding data code appears on the Data bus of the Microcontroller which is then read by the controller through the READ$KEYB routine.

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6.5 Display PCB D932

6.5.1 Connections

The display PCB consists of a Display Driver IC 7218B and the seven segment displays. The Display driver is mapped at address 8000H. Thus it is configured to receive the Code at 8000H and the data values from 8800H.

The data segments are configured as…

1. mAs Unit
2. mAs tens
3. mAs Hundreds
4. kV Unit
5. kV Tens
6. kV Hundreds

The same data locations are used for error code display also. In such case the Error code is displayed.

6.5.2 Interface with Master Card

The connection for the display card is obtained by 28 pin Flat Band DIP connector which carries the necessary signals for the IC 7218 from Master card to Display PCB. The Eighth line of the controller is used for error LED Displays on the Master Card.

6.6 Switch Mode Power Supply 40 watts

6.6.1 Specifications

The Switch mode power supply is used to supply + 5 Volts to the controller and associated circuitry and ± 15 V to the driver circuits.

The following are the specifications of the supplies.

+ 5 V at 3 Amps with Tolerance of 3%

+ 15 V at 0.3 Amps with Tolerance of 10 %

- 15 V at 0.2 Amps with Tolerance of 5 %

This output is maintained for the following range of the input conditions.

180 V ac to 260 V ac at 50 Hz ± 5 Hz and an input current of 0.7 Amp rms.

All out puts are protected for short circuit conditions and a sharp repeatitive sound is heard from the SMPS in the event of short circuit. The circuit behaves normally upon the removal of the short circuit.

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6.7 Switch Mode Power Supply 120 watts

6.7.1 Specifications

The Switch mode power supply is used to supply + 24 Volts to the Filament and associated circuitry.

The following are the specifications of the supplies.

+ 24 V at 5 Amps with Tolerance of 3%

This output is maintained for the following range of the input conditions.

160 V ac to 265 V ac at 50 Hz $\pm$ 5 Hz and an input current of 0.7 Amp rms.

All outputs are protected for short circuit conditions. The circuit behaves normally upon the removal of the short circuit.

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